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OPTOELECTRONIC SWITCHES AND APPLICATIONS

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Photoactivated or optoelectronic (OE) switches whose resistance is controlled by light are emerging as attractive and often unique devices for sampling and control of electrical signals, complementing advanced electronics. We review the characteristics of these switches and their potential application to ultra high speed time division multiplexing (TDM)¹ and to switching of microwave (mw) signals such as for reconfiguring antennas² and for the sampling of a coherent radar clock.

OE switches are metal-semiconductor-metal structures whose behavior can range from photoconductive to depletion-layer photodiode depending upon the semiconductor, the type of contacts, and the activating light intensity. Attractive features include high speed (< 50 ps), modest on-chip power dissipation, signal-control isolation, and compatibility with microelectronics and with mw transmission lines. Furthermore the use of optical fibers to transmit activating light to the switches, yields complete switch isolation, absence of pickup, excellent timing control, and low jitter. The present work concentrates on Si and InP switches and is limited to laser diode sources for practicality.

To first approximation, a switch can be treated as a variable resistor in parallel with a capacitance. In this work electrode gaps are either interdigital or rectangular and range in width from 1.5 to 20 μm . Capacitance ranges between 10-100 fF. For the TDM digital sampling, unannealed contacts on InP are used giving photodiode behavior. For the mw applications, ohmic contacts on Si are used giving photoconductive behavior. Laser pulses of < 40 ps and $\sim \text{pJ}$ incident upon InP switches gives $R_{\text{on}} \sim 3$ k Ω , cw power of ~ 20 mW upon Si switches yields $R_{\text{on}} \sim 25$ Ω , and for both cases $R_{\text{off}}/R_{\text{on}} > 100$.

Time Division Multiplexing

Ultra high speed networks offer greatly improved high performance computing. Essential to advanced networking is time

multiplexing data over serial channels, allowing optimum use of the transmission medium, optical fibers, and of switching. An OE-TDM link concept is shown schematically in Fig. 1 and a simplified 8-bit, 6.6 Gb/s experiment with an external clock is described. The multiplexer and demultiplexer consists of 8 interdigital switches having an area of $60 \times 60 \mu\text{m}^2$ and $2\text{-}\mu\text{m}$ fingers and $2\text{-}\mu\text{m}$ gaps fabricated on semi-insulating InP. These switches formed a linear array intersecting to make a 1.2 mm -wide metal pad. Optical control pulses of $<40 \text{ ps}$ FWHM from a gain switched AlGaAs laser diode were divided by a fanout coupler into 8 $50\text{-}\mu\text{m}$ core optical fibers. The fiber lengths were trimmed to provide 150 ps (30 mm) differential path delays corresponding to a 6.6 Gb/s serial rate.

As a dc bias of 10 V was applied to the 8 multiplexer inputs and optical pulses of $\sim 0.5 \text{ pJ}$ activated the switches, the serialized bit stream was produced. This signal was amplified by 38 dB and transmitted to the demultiplexer where its output channels were characterized. Histogram measurements of the demultiplexed channel amplitude and rms noise were made for various bit patterns and, assuming Gaussian noise, we inferred a bit error rate $<10^{-15}$, a figure suitable for computer networks. The fiber distribution scheme in addition to offering good timing control and stability operates with a clock at the word or frame rate instead of the bit rate, an substantial advantage for a data transmitted clock system.

Microwave Switching

OE switching may enable important mw application concepts, including the following two of military interest. First, ships and aircraft suffer from antenna crowding and the concept of multifunction antenna using OE switched segments is very attractive. Figure 2 illustrates this concept with a simple dipole antenna. Second, coherent radars presently can resolve features small enough to analyze ships, but higher speed sampling of a coherent radar clock is needed to resolve aircraft targets. OE switching, offering qualitative improvements in speed, EMI, and jitter over electronic switches, may enable this advanced application.

Switch requirements are similar for both uses. The impedance of a mw transmission line and an antenna element are in the range of $50\text{--}100 \Omega$, therefore ideally $R_{\text{on}} < 50 \Omega$ and $Z_{\text{off}} > 100 \Omega$. Frequencies of interest for antennas are $1\text{--}18 \text{ GHz}$, for the clock 1.3 GHz . Required switch transition times differ, being ms for antenna reconfiguration and $<200 \text{ ps}$ for clock sampling. These OE switching times are readily obtained. Power switched is $\sim 10 \text{ mW}$ for the clock and initially $\sim .5 \text{ W}$ for antennas.

Switches were fabricated on high resistivity (1000 Ω -cm) Si with ohmic contacts using standard MOSFET processing. Preliminary tests as noted above give R_{on} ~25 Ω under 20 mW cw illumination and R_{off} ~1500 Ω which is encouraging. Simple theory indicates decades of improvements are possible in lowering R_{on} and reducing the required illumination. Recent results will be presented.

Summary

Optoelectronic switches to complement advanced electronics are introduced and potential applications are described. Sampling of digital signals in ultra high speed network TDM was demonstrated at 8-bits and 6.6 Gb/s serial rate with excellent S/N. This application illustrates OE speed, timing control and stability, word clock rate, and electronic fabrication compatibility. Switched-element antenna reconfiguration and radar clock sampling appear unique OE applications. In antennas, switch isolation owing to optical fiber control lines is a decisive feature. For clock sampling, OE switch speed and timing stability are the dominant features. The TDM use appears within the present art while for the mw switching the technology requires some further development for optimum use.

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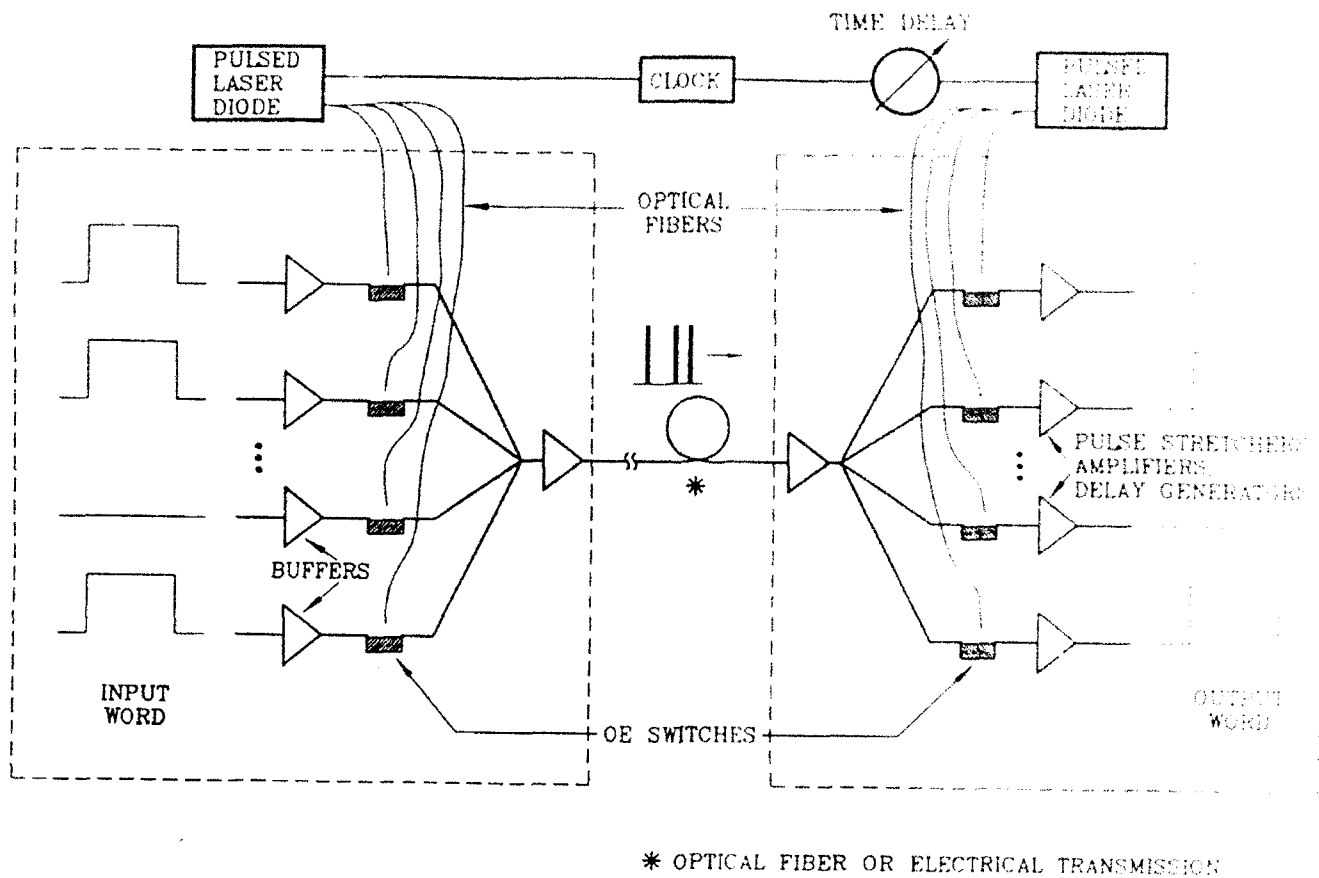


Fig. 1. Schematic of the OE-TDM concept with an external clock.

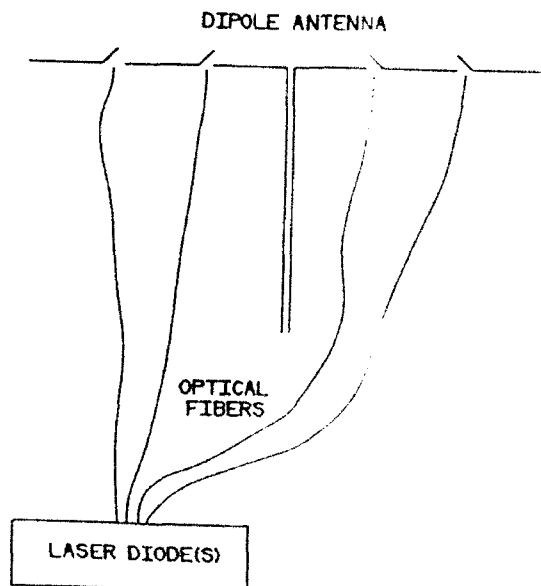


Fig. 2. Schematic of a switched reconfigurable dipole antenna.